(12) EUROPEAN PATENT APPLICATION

(54) Method of making optical fibres and optical fibre preforms.

(57) A method of making a high birefringence optical fibre comprises depositing a layer of glass of a first expansivity on the inside of a tube of a second expansivity, differentially etching the layer to form two diametrically opposed strips, depositing a third layer of glass over the strips and shrinking the preform to form a glass fibre with a conventional sheath (24) and core (26) clad with an asymmetrical layer of doped (22) and undoped (20) glass.
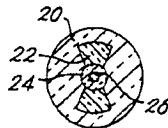
Fig. 2

EP 0 098 102 A1

METHOD OF MAKING OPTICAL FIBRES AND OPTICAL FIBRE PREFORMS

This invention relates to the preparation of optical fibres having a high birefringence, and relates particularly to the preparation of a preform from which such fibres can be drawn. Highly birefringent fibres have stable fast and slow polarisation

05 axes, and linearly polarised radiation can therefore be transmitted along either axis. The fibre output polarisation state is thus linearly-polarised and remains largely unaffected by fibre perturbations, such as kinks, bends and side pressure which in conventional fibres produce major changes in output state. The fibre is

10 consequently useful in applications requiring a defined output polarisation state, such as fibre interferometers.

Fibre birefringence can be induced by introducing a large asymmetric stress in the fibre core and, to a lesser extent, in the cladding. A refractive index difference along the axes of

15 stress asymmetry is produced as a result of the stress optic (photo-elastic) effect and the fibre appears birefringent. The stress can be generated by constructing the fibre of materials which have different coefficients of thermal expansion, the materials being arranged asymmetrically about the longitudinal

20 axis; for example two different glasses can be used in the cladding of a fibre preform.

A variety of methods have been used to prepare birefringent fibres. One method is the sawing technique in which a circular, highly-doped preform is made by a conventional chemical vapour

25 deposition process. It is then sawn along two sides with a diamond saw. Subsequently it is re-circularised by rotating and heating a glass-working lathe, producing a preform of elliptical cross-section. With this method, only low levels of stress can be obtained, since attempts to saw highly-stressed preforms result in cracking. It

30 is also difficult to control the process accurately. In another method, two grooves are machined along the length of a low-stress preform. Glass rods with a high expansion coefficient are then placed in the grooves. The preform is sleeved to contain the rods and pulled into a fibre. This method has the disadvantages that

it is difficult to maintain a constant distance between the two rods and core, there may be a mismatch between the softening temperature of the preform and the rods and lack of uniformity of the rods may result in asymmetric stress characteristics. Yet

05 another existing method layers of highly doped glass are deposited inside the quartz substrate tube. Strips of photo-resist are deposited longitudinally on the outer surface and the exposed areas etched. Subsequently a standard cladding and core are deposited to produce the desired asymmetric prefrom. This method

10 is vulnerable to the introduction of cracks in the mechanical processing and the etching has to be repeated a number of times since acid etching attacks the resist as well as the glass.

In order to overcome many of the drawbacks of these method we have now developed a method of producing high birefringent fibres

15 based on vapour phase etching.

According to the invention there is provided a method of preparing a preform for a high birefringence optical fibre comprising the successive steps of exposing a hollow tube of a first glass simultaneously to an etching gas and a high temperature at

20 two areas parallel to the tube axis and at diametrically opposite positions to remove two strips of glass in a direction parallel to the axis of the tube, applying to the inside of the tube a layer of an optical cladding material, applying to the inside of the cladding material a layer of core material and collapsing the tube to form

25 an optically axially-asymmetric fibre optic preform.

Preferably the method comprises the additional, first step of applying to the inside of the tube of a first glass a layer of a second glass having a coefficient of thermal expansion substantially different from that of the first glass, the etching step

30 then removing two parallel strips of the second glass.

The etching gas may be a gas which releases fluorine when heated, and the high temperature may be applied by one or more gas flames arranged to traverse the length of the glass tube so as to heat an area of the tube of small circumferential extent.

35 The preform may be drawn into an optical fibre by any suitable method.

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The invention will now be described by way of example only with reference to the accompanying drawings in which:-

Figures 1(a) to 1(f) are cross sections of an optical fibre preform illustrating successive stages during its preparation;

Figure 2 illustrates the cross section of a fibre drawn from the preform;

Figure 3 illustrates schematically the apparatus used to prepare the preform;

Figure 4 illustrates part of the preform after the etching step;

Figures 5(a) and 5(b) illustrate stages of an alternative preparation method; and

Figure 6 shows in cross section an alternative preform.

Figure 1(a) shows a precleaned circular substrate tube 10, for example a silica tube. A layer of a glass having a coefficient of thermal expansion substantially different from silica is deposited as an even layer 12 within the tube 10 (Figure 1(b)). For example a doped silica glass may be deposited by the well known technique of chemical vapour deposition. Typical dopants are B_2O_3, GeO_2 and P_2O_5 which will increase the expansion coefficient of silica. In particular, P_2O_5 and B_2O_3 have a large effect. The layer 12 is typically built up of many component layers, and its refractive index may be adjusted to be above or below that of the substrate tube by admixtures of GeO_2, P_2O_5, AL_2O_3, which increase the refractive index, and B_2O_3 and fluorine, which decrease the refractive index.

The layer of doped glass 12 is then etched to remove two diametrically opposite longitudinal strips, see Figure 1(c), the etching continuing until the doped glass is completely removed in these two areas. The etching is achieved by passing a fluorine-containing gas into the tube, and heating the outside of the substrate tube 10 in the areas in which etching is required; the heat liberates fluorine which attacks the glass.

After etching, the substrate-tube bore has four separate regions; two regions coated with doped silica, and two regions from which the doped silica has been entirely removed. The relative

sizes of these regions can be easily controlled, in accordance
with requirements in the completed preform, by varying the circum-
ferential extent of the hot zones used in the etching process.

A layer 14 of low-loss optical cladding material is now
05 deposited on the etched layer, Figure 1(d), and a layer 16 of core
material is deposited on the cladding layer, Figure 1(e). The
cladding and core materials may be deposited by chemical vapour
deposition. The core is typically germania/silica and the cladding
is typically silica or lightly-doped silica. The tube is then
10 heated to a sufficiently high temperature for the action of surface
tension to collapse the tube. A small internal positive pressure
is maintained during the process to give an optical fibre preform 18
having the cross-sectional construction illustrated in Figure 1(f),
i.e. with two regions of doped glass 12' spaced from a central
15 core 16' surrounded by a layer of cladding 14' and embedded in a
substrate layer of undoped glass 10' having a circular external
surface. The doped regions form a "bow tie" shape. The preform 18,
when drawn down by any suitable method, gives an optical fibre
having a cross section as illustrated in Figure 2, with an asym-
20 metrical arrangement of undoped glass 20 and doped glass 22. The
difference in coefficients of thermal expansion between the
regions 22 and 20 causes asymmetric stresses in the fibre, and a
high level of birefringence is present.

The doped glass layer 22 need not have any optical function;
25 it may merely generate stress in the optical fibre, but to prevent
unwanted propagation effects it preferably has an optical index
equal to or less than that of the silica substrate 10'.

The high-thermal expansion regions of doped glass 22 in the
final fibre should approach the fibre core 26 as closely as
30 possible to impart maximum thermal stress to the core and thus
maximum birefringence, but to achieve low optical loss an optical
cladding 24 must surround the core 26 to a distance of several
times the core radius. These conditions are achieved by varying
the thickness of the deposited layers. To prevent unwanted guidance
35 of light in the optical cladding 24, it preferably has an index
equal to or less than that of the substrate 20.

The cross-sectional geometry of the drawn fibre illustrated in Figure 2 is close to the optimum shape predicted by mathematical theory. With such a cross-section, the refractive index conditions for optimum propagation are:-

05

$$n_{26} > n_{20}$$
$$n_{24} \leqslant n_{20}$$
$$n_{22} \leqslant n_{20}$$

One form of apparatus suitable for preparing the preform is illustrated in Figure 3. The tubular glass substrate 10 is fixed in a glass-working lathe, indicated in highly schematic form. The lathe comprises two end pieces 30, 32, each carrying an end support 34, 36, in which the substrate 10 is fixed and which can rotate the tube about its longitudinal axis as indicated by the arrows. A gas inlet pipe 38 is connected to the endpiece 30, and a gas exhaust pipe 40 is connected to the endpiece 32. Adjacent the tube 10 is a gas burner 44 which is reciprocatable along a support 46 parallel to the axis of the tube 10; the support 46 has a gas supply tube 48.

In use the substrate 10 is rotated and heated by the recipro- cating burner 44. A mixture of gases is supplied through the tube 38 so that a layer of doped glass is deposited evenly on the inside of the substrate by chemical vapour deposition. For example 10 to 30 layers each 10 micrometres thick may be deposited. The gas may be any mixture of $SiCL_4$, BBr_3, $POCL_3$, $GeCL_4$ and F_2 plus O_2.

Rotation of the substrate is then ceased. An etching gas is now supplied through the tube 38 and the gas burner 44 is slowly traversed along the outside of the tube. The heat applied to the outside of the substrate 10 causes etching of the corresponding part of the doped glass inside the substrate. The rate of etching depends upon the concentration and flow rate of the etching gas and the temperature. The flame size is chosen in accordance with the area it is required to remove, but the heating will always be local. Many passes may be needed and usually the slow traverse always occurs in the same axial direction, followed by a fast return to the starting position at one end. To provide the second

etched area, either the substrate 10 is rotated through 180°
between forward traverses of the gas burner 44, or a second
burner 45, shown dotted in Figure 3, is traversed simultaneously
at a position diametrically opposite the burner 34.

05   Typically the etching gas is SF_6 or CCl_2F_2, but any other
fluorine-liberating gas may be used. The etching gas may be mixed
with oxygen or diluted with an unreactive gas such as nitrogen.
The temperature in the locally heated area is typically 1200°C to
1500°C. At the higher temperature etching can be completed in

10   about 30 minutes using 10 traverses of the gas burner.

        Figure 4 illustrates the external appearance of the substrate
tube 10 after etching. As each of the incremental layers (up to
30) of deposited doped glass is etched away, an edge forms which
is visible through the substrate as indicated by the lines 42.

15   Each incremental layer forms four edges, spaced round the tube
circumference. The positions of the edges change as etching
proceeds, and can be used to decide when etching should be
terminated.

        The gas burner 44 is now extinguished, and the appropriate

20   gases supplied in sequence through the supply tube 38 to deposit
an optical cladding layer and a core layer as in the well-known
chemical vapour deposition procedure. The substrate 10 with its
internal coating layers is then collapsed at a higher temperature
to form an optical fibre preform.

25   In a variation on the method, illustrated in Figures 5(a)
and (b), steps essentially as outlined above may be followed, but
the diametrically opposed etching of the internal deposited
layer 52 on the substrate tube 50 by the traverse of one or two
gas burners is not taken to completion. The layer is therefore

30   not entirely removed, but merely thinned in two longitudinal
strips 58 as shown in Figure 5(a). The cladding 54 and core 56
are applied as before and the coated substrate collapsed to give a
preform with the cross-sectional geometry shown in Figure 5(b).
The approximately elliptical region 52' has a high-expansion

35   coefficient and serves to provide asymmetric stress aligned with
the major and minor axes.

In this case the step in which a doped layer is deposited
inside the substrate tube and subsequently etched may be omitted
and etching performed directly on the substrate tube with the
purpose of reducing its wall thickness in two longitudinal strips.

05 An elliptical internal-geometry will be formed in the cladding and
core layers and this can be used to provide stress asymmetry and
birefringence.

With the cross-section illustrated in Figure 5(b), the
refractive index conditions for optimum propagation are:-

10
$$n_{56} > n_{50}$$
$$n_{54} \leqslant n_{52}$$
$$n_{52} \leqslant n_{50}$$

In a further variation, the outside wall of a substrate tube
is etched and thinned by introducing a fluorine-liberating gas

15 into the flame of the gas burner 34. After deposition and collapse,
the resulting preform can have a geometry similar to that shown in
Figure 5(b), since the preform tends to circularise under the
action of surface tension during the collapse process and the less
viscous inner layers become elliptical in cross-section.

20 A modification of the external-etch process removes material
from diametrically opposed horizontal strips of the preform after
collapse to give an approximately circular preform. During drawing
the resulting fibre tends to circularise, giving an elliptical
internal cross-sectional geometry similar to that of Figure 5(b).

25 It should be understood that it is possible and in many cases
advantageous to first deposit inside the substrate tube a layer of
low-loss glass which may be undoped silica, or a layer of lightly
doped glass with an index equal to or slightly less then silica.
Typically this is a co-doped fluorine/P_2O_5 silica layer which has

30 relatively high viscosity. The layer acts to buffer the subse-
quently deposited layers from the diffusion of hydroxyl contaminant
from the substrate tube into the optical region. The arrangement
after collapse is illustrated in Figure 6; the low-loss glass 61
is deposited on the substrate tube 60, and is coated in turn with

35 a doped glass 62, a cladding layer 64 and a core layer 66. The

similarity with Figure 2 will be evident. The refractive index

conditions for optimum propagation are:-

$$n_{66} > n_{61}$$

$$n_{64} \leqslant n_{61}$$

05

$$n_{62} \leqslant n_{61}$$

$$n_{61} \leqslant n_{60}$$

Such a layer may also be applied when the Figure 5 configuration

is used.

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CLAIMS

1.   A method of preparing a preform for a high birefringence
optical fibre comprising the successive steps of exposing a hollow
tube of a first glass simultaneously to an etching gas and a high
temperature at two areas parallel to the tube axis and at dia-
05   metrically opposite positions to remove two strips of glass in a
direction parallel to the axis of the tube, applying to the inside of
the tube a layer of an optical cladding material, applying to the
inside of the cladding material a layer of core material and
collapsing the tube to form an optically axially-asymmetric fibre
10   optic preform.

2.   A method of preparing a preform for a high birefringence
optical fibre as claimed in Claim 1 further comprising the step of
applying to the inside of the tube a first layer of a second glass
having an expansivity different from that of the first glass and
15   then exposing said first layer simultaneously to the etching as
and the high temperature.

3.   A method of preparing a preform as claimed in either Claim 1
or Claim 2 wherein the etching gas is a gas which releases fluorine
when heated.

20   4.   A method of preparing a preform as claimed in any one of the
preceding claims wherein the high temperature is applied by means
of gas flames which are moveable relative to the tube to heat an
area of the tube of small circumferential extent.

5.   A method of preparing a preform as claimed in Claim 2 wherein
25   the second glass consists of silica and a dopant material.

6.   A method of preparing a preform as claimed in Claim 5 wherein
the dopant is germania.

7.   A method of preparing a preform as claimed in Claim 5 wherein
the dopant is phosporus pentoxide.

30   8.   A method of preparing a preform as claimed in Claim 5 wherein
the dopant is alumina.

9.   A method of preparing a preform as claimed in Claim 5 wherein
the dopant is boron trioxide.

10.   A method of preparing a preform as claimed in Claim 5 wherein
35   the dopant is fluorine.

- 10 -

11. A preform for the preparation of a high birefringence optical
fibre comprising a tube of a first glass having two diametrically
opposed strips of a second glass having a expansivity different
from that of the first glass on its inner surface and a layer of
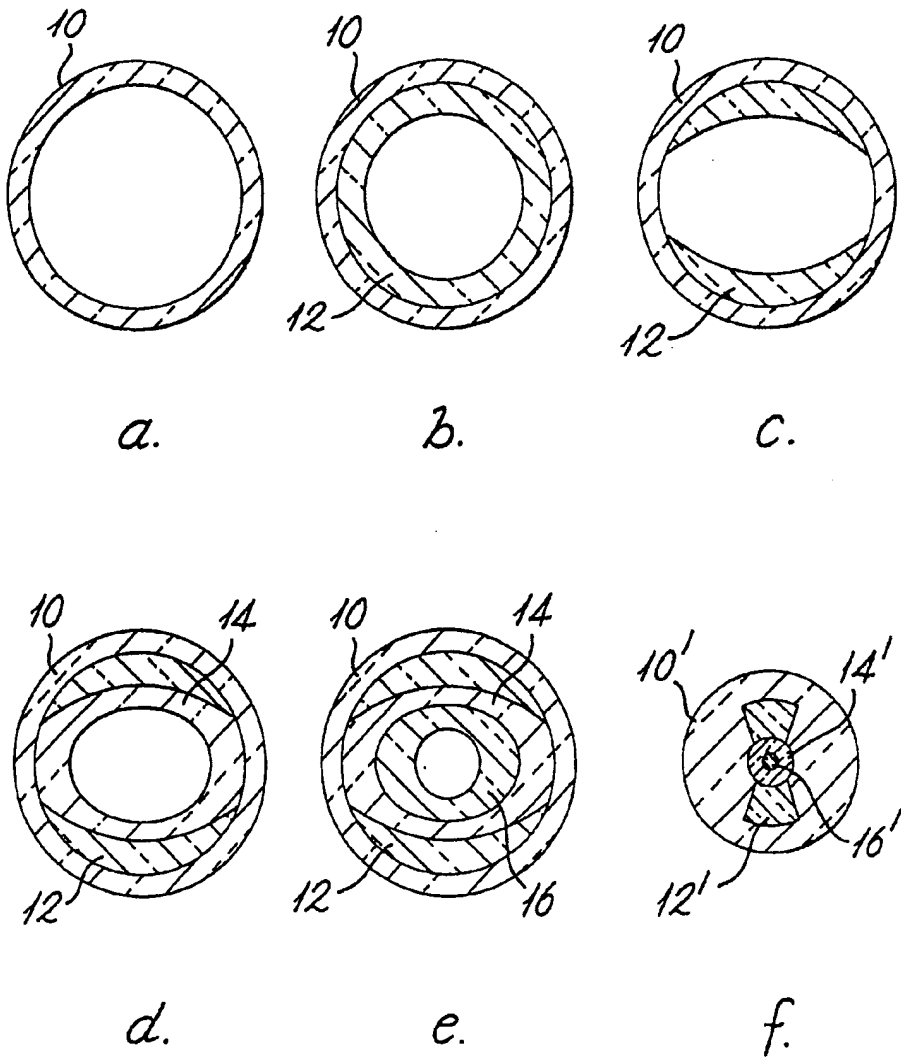05 a third glass on within said tube covering said diametrically
opposed strips.

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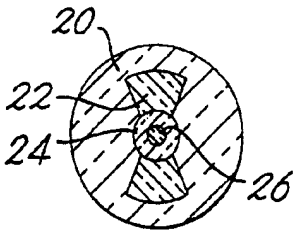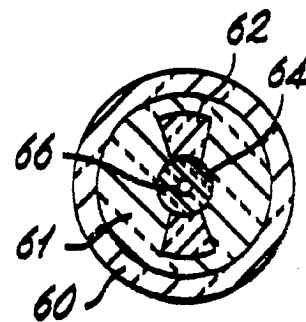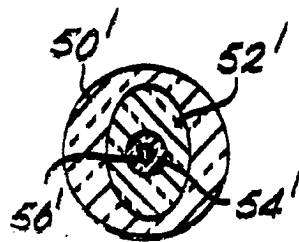a.   b.   c.

d.   e.   f.

Fig. 1

Fig. 2

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Fig. 3

Fig. 4

Fig. 5a   Fig. 5b   Fig. 6

European Patent Office

EUROPEAN SEARCH REPORT
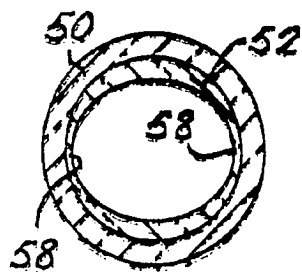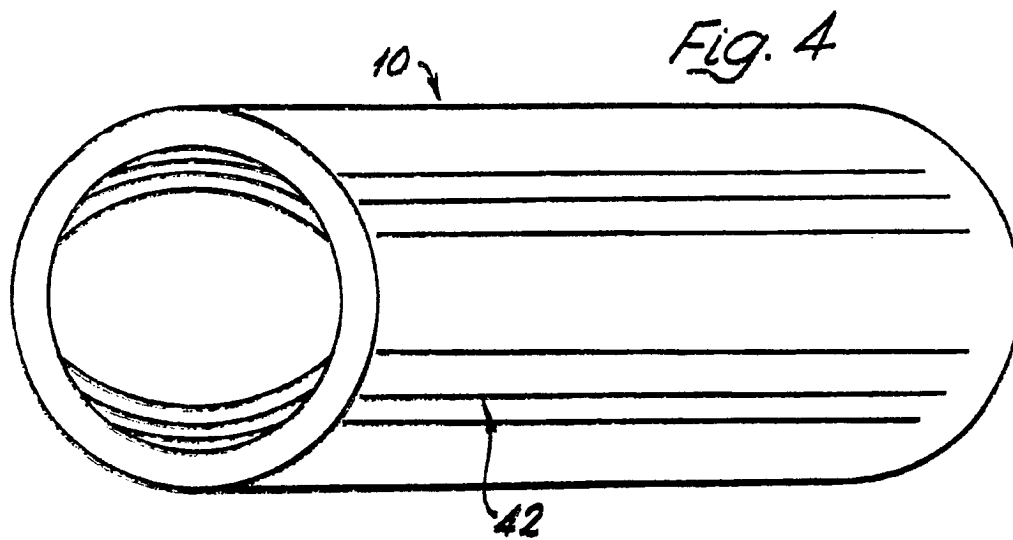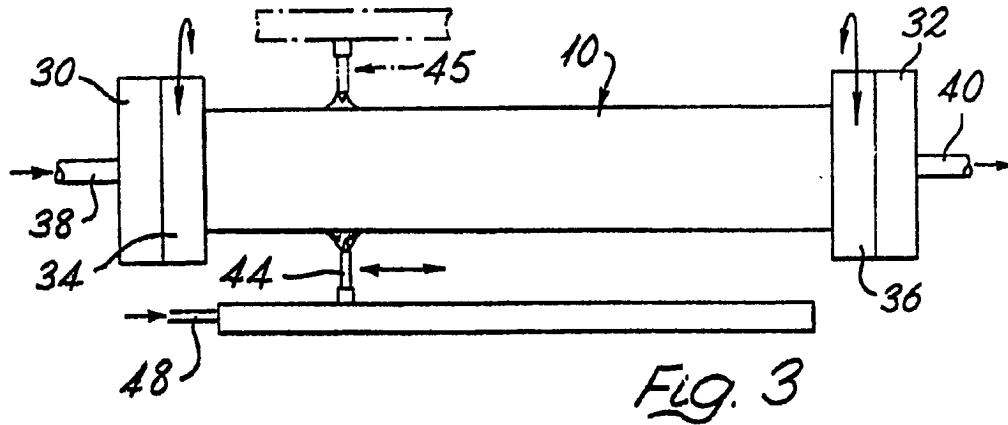
	DOCUMENTS CONSIDERED TO BE RELEVANT		EP 83303621.3
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
X	<u>DE - A1 - 2 930 781</u> (LICENTIA) * Claims 1,5,6; page 8, lines 18-24; fig. 9A *	11	C 03 B 37/025 G 02 B 5/14
A	<u>US - A - 4 274 854</u> (PLEIBEL) * Column 1, lines 28-58; column 4, lines 1-8; claims 1,2,6,7; fig. 1-5;	1,5,9	
A	APPL. PHYS. LETT., vol. 33(9), November 1st, 1978, American Institute of Physics, Knoxville, Tennessee V. RAMASWAMI et al. "Single polarization optical fibers: Exposed cladding technique" pages 814-816 * Page 815, left column, lines 3-8, line 28 - right column, line 13; fig. 2 *	1	
A	<u>EP - A1 - 0 017 742</u> (SIEMENS) * Claims; fig. 1-5 *	1,2,11	**TECHNICAL FIELDS SEARCHED (Int. Cl. ³)** C 03 B G 02 B C 03 C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	26-09-1983	HAUSWIRTH